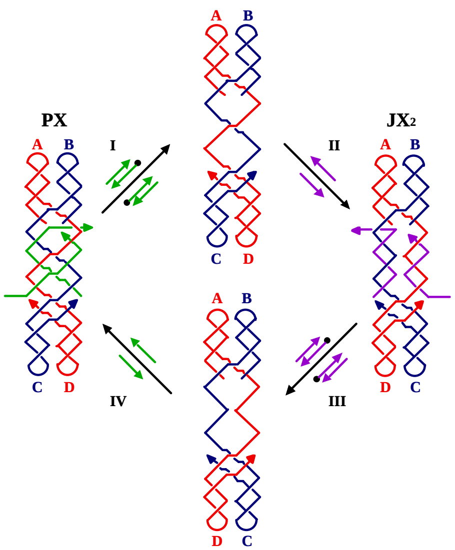
A Sequence-Dependent DNA Nanomechanical Device

The reason to make a sequence-dependent DNA device is that an array of N different devices can be controlled to give 2^N distinct states, thereby facilitating nanorobotics.

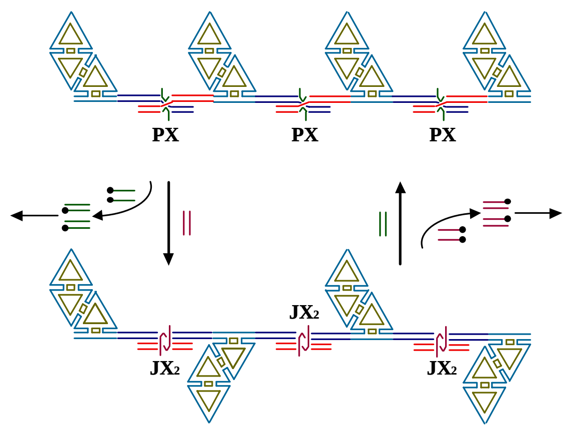
Principles of Operation

Conversion between 2 states, called PX and JX$_2$, is accomplished by the addition of ‘fuel’ strands to remove ‘set’ strands that determine the state of the device. Addition of a new set strand to the intermediate state lacking strands will set a new state of the device. The machine cycle is shown below. Starting with the PX state on the left, green fuel strands remove green set strands. Then adding purple set strands converts the intermediate (top) to the JX$_2$ state. The PX state can be restored as shown at bottom.



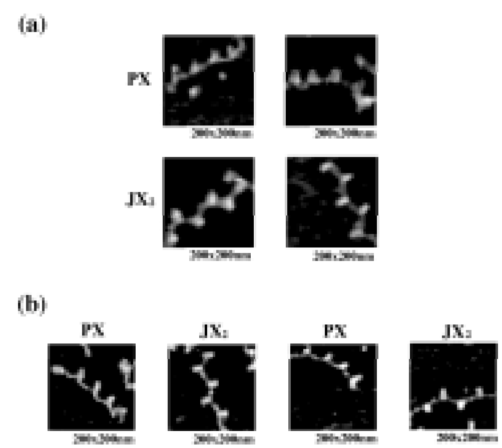
AFM System to Test the PX-JX$_2$ Device

The system consists of two components, half-hexagons formed from edge-sharing fused DNA triangles, and PX-JX$_2$ devices that connect them. In the PX state, all of the half-hexagons should be pointing in the same direction, a ‘cis’ arrangement shown at the top of the figure. However, removal of the green strands, and the addition of the purple strands converts the system to the JX$_2$ state,shown at the bottom of the drawing.



AFM Evidence for Operation of the PX-JX$_2$ Device

Shown below are atomic force micrographs of the system shown in the middle panel. Section (a) contains control images, half-hexagons held together by non-device molecules enforced to be in the PX state, or the JX$_2$ state. Note the parallel nature of the PX image and the zig-zag nature of the JX$_2$ image. Section (b) shows four successive states of the same system, but now held together by the device, rather than fixed molecules. Note the alternation of pattern as the state changes..



Yan, H., Zhang, X., Shen, Z. & Seeman, N.C. (2002), *Nature* **415**, 62-65.

Structural DNA Nanotechnology Performed by High School Students

Despite the fact that there are some structural and topological subtleties to structural DNA nanotechnology, many of the manipulations are really easy enough for talented high school students to perform. Three high school students are working in our lab right now, largely under the direction of Phil Lukeman, a postdoc. John Sadowski is examining the nanotechnological implications of M-DNA in branched molecules. Rob Barish is studying the possibility of converting the sequence-directed nano-mechanical device into a 3-state system, where the third state is a translational variant. The third student, Alex Mittal, has shown by atomic force microscopy that peptide nucleic acid molecules can be incorporated into DNA lattices, possibly obviating the need for Mg^{2+}, that makes DNA incompatible with metallic nanoparticles.. For this work, he won, among others, the Intel Foundation Young Scientist Award, the Intel Foundation Achievement Award, the Intel ISEF Best of Chemistry Award, and the Intel Chemistry First Award in 2002. His winning poster is shown below.